

# Progress Report

May 2000

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## Table of Contents

Introduction.....	3
Implementation Achievements .....	3
Lake Tahoe, CA, USA .....	3
Thangoo, WA, Australia .....	7
Amburla NT, Australia .....	8
Uardry, NSW, Australia.....	8
Science Results .....	9
Publications and Media.....	10
Collaborations .....	11
Archiving .....	11
Future Plans .....	11
Schedule.....	12
HomePage .....	12

## List of Figures

Figure 1. Mk IV raft at L. Tahoe with double solar panels, radiometer and temperature loggers on thermistor chain.....	5
Figure 2. A YankeeTotal Sky Imager (TSI) and Yankee Multi Filter Rotating Shadowband Radiometer (MFRSR) on new mount above gauging station. ....	6
Figure 3 In Situ Derived Kinetic Temperature and Kinetic Temperature Difference (Image derived minus In situ) versus Image Derived Kinetic Temperature. (Plot courtesy of F. Palluconi) .....	10

## **Introduction**

In 1997 a proposal was submitted to the Satellite Remote Sensing Measurement Accuracy, Variability, and Validation Studies NASA Research Announcement entitled:

“Validation of Thermal Infrared Data and Products from MODIS and ASTER over Land”

The objective of the proposal was to validate the thermal infrared data and products acquired over land from the Advanced Spaceborne Thermal Emission Reflectance Radiometer (ASTER) and the Moderate Resolution Imaging Spectroradiometer (MODIS) using a set of automated validation sites. The main advantage of this approach is the validation data are acquired automatically allowing validation whenever satellite data are acquired and monitoring of accuracy and precision of the satellite data and products over time. The proposal was accepted and 4 automated validation sites were identified. The sites were L. Tahoe, CA, USA; Thangoo, WA, Australia; Amburla, NT, Australia and Uardry, NSW, Australia. The subsequent report is divided into six main sections: Implementation Achievements, Science Results, Publications and Media, Collaborations, Archiving, Future Plans and Schedule. The Implementation Achievements section summarizes the status of each site, for a detailed description of each site, the reader is referred to the 1999 status report. The Science Results section provides examples of how the data that have been acquired are being used. The Collaboration section describes how the sites have been incorporated into the work of other Instrument teams. The Archiving section discusses how the field data are being archived. Finally the Future Plans section covers what additional equipment is being added.

## **Implementation Achievements**

### **Lake Tahoe, CA, USA**

The Lake Tahoe site has been semi-operational for approximately one year. During that time numerous improvements have been made to both the infrastructure and instrumentation to provide better validation datasets. The improvements include:

*Deployment of 2 remaining rafts.* This was accomplished in June of 1999 as planned.

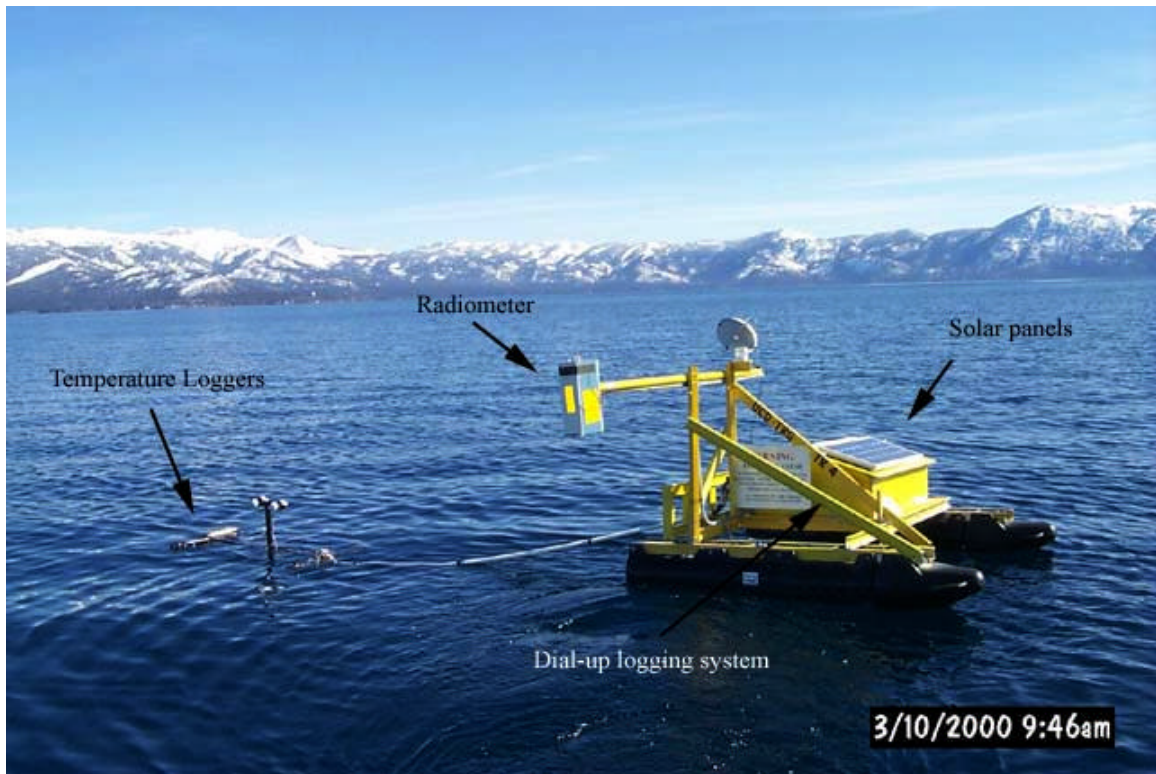
*Addition of dial-up data acquisition systems to each raft.* A dial-up acquisition system has been added to each of the rafts. Each system records the data from the radiometer and 4 temperature loggers. The loggers are attached to a floating mount behind each raft (Figure 1). Each logger is approximately 2 cm beneath the surface. The data from the radiometers and loggers are automatically downloaded to JPL daily. This system is especially useful for quickly identifying any problems with the radiometers or temperature loggers thereby minimizing any down time. The original temperature loggers, which record to static memory, are co-mounted with the dial-up loggers

providing extra redundancy. Data from these loggers were used to determine an error in the calibration of the thermal infrared band of Landsat (see Collaborations section).

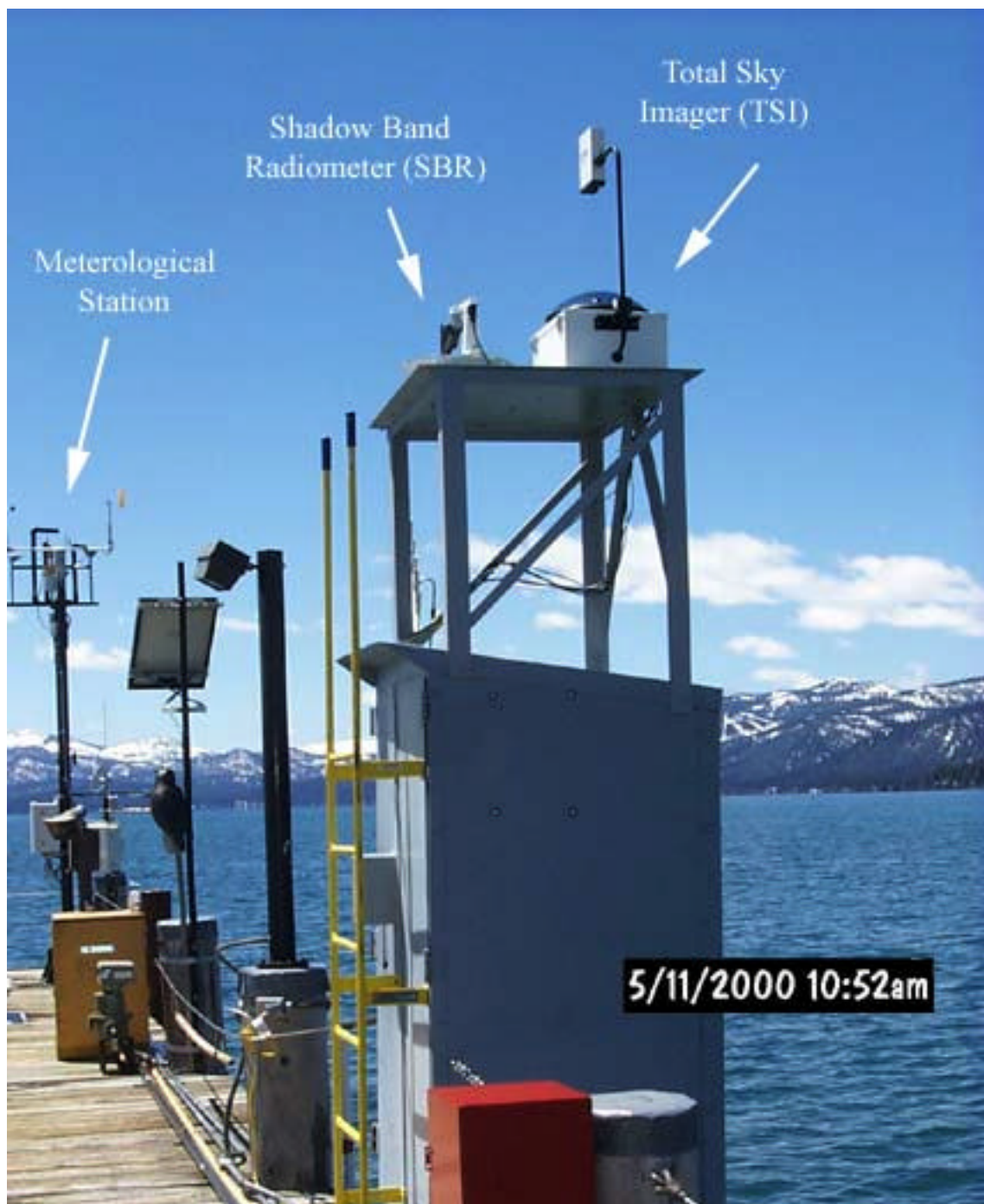
*Addition of two 50 watt solar panels, 4 deep cycle batteries and protective enclosure to each raft.* During the winter months power to the rafts failed due to unusually long periods of complete cloud cover (several weeks). Two solar panels were added to each raft and additional batteries allowing the system to fully charge more rapidly as well as operate under complete cloud cover for extended periods. Since the addition of the extra solar panels and batteries there have been no power failures. Also a protective enclosure had been added to each raft that houses and protects the data acquisition system and batteries (Figure 1).

*Improved radiometer design.* Several modifications have been made to the radiometers to improve their reliability and accuracy, for example, an improved motor mechanism. A third-generation radiometer has been developed that is undergoing testing which will be deployed shortly. The second-generation radiometer includes a blackbody that changes temperature according to the temperature of the target (not the ambient air temperature). This should improve the accuracy of the radiometer measurements, especially in situations where using the current radiometers it is necessary to extrapolate the blackbody temperatures to the scene temperature.

*Deployment of the Multi Filter Rotating Shadowband Radiometer (MFRSR) and Total Sky Imager (TSI).* The MFRSR was deployed on the US Coast Guard pier in June of 1999 as planned. However, problems were experienced with the stability of the mount and alignment of the MFRSR. As a result a new mount was manufactured and attached to the gauging station part way down the pier (Figure 2). A telephone line was installed in the gauging station and connected to a computer inside the gauging station. This allowed the computer that controls the MFRSR and TSI to be controlled remotely via phone connection. Again this allows any problems to be quickly identified minimizing down time as well as rapid access to data.



**Figure 1. Mk IV raft at L. Tahoe with double solar panels, radiometer and temperature loggers on thermistor chain.**



**Figure 2. A YankeeTotal Sky Imager (TSI) and Yankee Multi Filter Rotating Shadowband Radiometer (MFRSR) on new mount above gauging station.**

## **Thangoo, WA, Australia**

This is a new site (started in 1998) chosen because it is in a monsoonal climate zone with water vapour loadings ranging from as low as 1 cm of precipitable water to values in excess of 7 cm during the wet season. In a typical year the wet season lasts from December to April. The remaining seven months are dry with the highest percentage of clear skies anywhere in Australia. The site is located in tropical savanna woodland (Acacia) and suffers occasional bushfires. The cycle of burning in tropical Australia is currently under intensive research and the choice of this site has been influenced by the need to collect information on biomass burning aerosols. Instruments at the site consist of a suite of radiation devices (pyranometers and pyrgeometers), a Yankee MFRSR for aerosol optical depth and water vapor measurements, and four CSIRO scanning radiometers. Some ground sensors are used, but the nature of the biome make relating understory surface temperature measurements to satellite measurements impractical. The approach taken has been to use the scanning radiometer measurements, mounted on telescopic masts about 6 m high, to measure the radiation from the canopy (average height 3-4 m) and understory. Data collected so far indicate that this works very well during the relatively thermal inactive nighttime, but difficulties arise during the day. Results using ATSR-2 imagery suggest that there are some strong angular effects during the day and these must be accounted for when validating thermal products. For ASTER validation we do not anticipate that this will be a problem because ASTER makes most of its measurements close to nadir. However, the Thangoo data will be very valuable for MODIS validation. Radiosonde data (daily) are obtained from the Australian Bureau of Meteorology's upper air station at Broome approximately 30 km from the site.

In November 1999 a large bushfire burnt out part of the site and damaged some of the equipment. Two of the radiometers were recovered from the site and serviced at CSIRO. Some electronics was also damaged. Landsat ETM imagery was acquired before and after the fire event and a time-series of data from the AVHRR and ATSR have also been acquired. These data will be used to fully investigate the effect of the fire on the vegetation and study the re-growth characteristics. During the 1999-2000 wet season it was decided to de-commission some of the instruments and only the central site and one remote site were left operating. There is telephone communication at the site and data are downloaded daily. Unfortunately on 19-20 April, 2000, a category 4 tropical cyclone passed over the site and caused severe damage to the area. A storm surge brought sea water 4 km inland and flooded the central site. Strong winds had already blown the instrumented caravan over. Up until 19 April data was being collected from the site. The instruments have now been recovered from Thangoo and the estimated damage is \$A 6K. This is very slight considering the strength of the storm. None of the radiation instruments were damaged (domes intact) and the MFRSR is also undamaged. Surprisingly, the central computer housed in the caravan was still operating, despite having been immersed in water.

Re-installation of the equipment will take place in May and June for the remainder of the dry season. The site character has changed from its initial state and we expect the

scanning radiometer measurements to be more suitable and less influenced by the few remaining trees.

### **Amburla NT, Australia**

This site was established in 1995 and is running at present. Like Uardry the site uses remote data collection and RF communication. The climate is semi-arid and the surface is predominantly bare, covered by a quartz-rich, red-colored soil. Occasional rain causes rapid growth (Mitchell grass) and the character of the surface can change markedly in a matter of days to weeks. Surface temperature is measured using ground sensors (similar to Uardry) and these have proven to be very reliable. A satellite telephone and two network phones allow us to download data daily. Apart from surface temperature, a full suite of radiation and meteorological measurements are made. There is a daily radiosonde flight made from Alice Springs (about 100 km away) and these data are routinely acquired.

In mid-2000 a CSIRO scanning radiometer will be deployed at Amburla. This will provide continuous measurements at 15 zenith angles, including a sky measurement and two blackbody views. We expect these data to come on line by August, 2000.

### **Uardry, NSW, Australia**

This site was first established in mid-1992 and has been running more or less continuously to the present. The atmospheric conditions are very favorable for remote sensing validation at this grassland site where aerosol optical depth at 550 nm rarely exceeds 0.05 and cloudiness is low. The site has a 15 m tower from which radiation measurements (shortwave and longwave) are made. Apart from standard meteorological measurements, aerosol optical depth is measured using a Yankee MFRSR and there are now several infrared radiometers deployed at the site. The remainder of this discussion will concentrate on a description of the new instruments deployed at the site, particularly those dedicated to thermal IR studies.

A unique feature of the Australian network has been the use of RF communication that allows data to be collected at several locations across the site and hence estimate the spatial heterogeneity of the site - a very important factor for thermal studies at scales of 100 -1000 m. Measurements of surface temperature have been conducted using in situ ground sensors (temperature transducers) and methods have been developed to ensure correct placement of the sensors. Over time, the spatial average of these sensors (up to 25 across a 1 km x 1km area) has been shown to be a very good measure of the surface temperature of a 1 km x 1 km area. Because of the homogeneity of the Uardry site we have been able to develop algorithms which can be applied to larger scales for grassland surfaces and relatively low water vapor loadings (up to 3 cm). Recently we have been exploring the use of narrowband IR radiometers for use in the field. Previous work on these has shown that great care must be taken in calibrating the radiometers and also in mounting them. We have developed a self-calibrating radiometer and tested a version of this at the Uardry site for 1 year. The success of the deployment has encouraged us to

deploy 3 more radiometers on the tower at Uardry. These view the surface below from a height of 15 m at three different zenith angles, viz. 0., 30., and 55. These angles allow us to investigate angular effects in surface emissivity and thermal BRF effects not associated with the atmosphere. During April a 2-day field experiment was conducted to test field equipment and cross-calibrate field instruments. Researchers from several CSIRO divisions acquired surface measurements at the site using spectrometers, field radiometers, sun photometers, and portable radiosonde equipment. Results from this experiment are currently being analyzed.

The infrared radiometers are now permanently deployed at Uardry, taking 10 s samples and reporting measurements every 2 minutes continuously. Standard deviations are also reported.

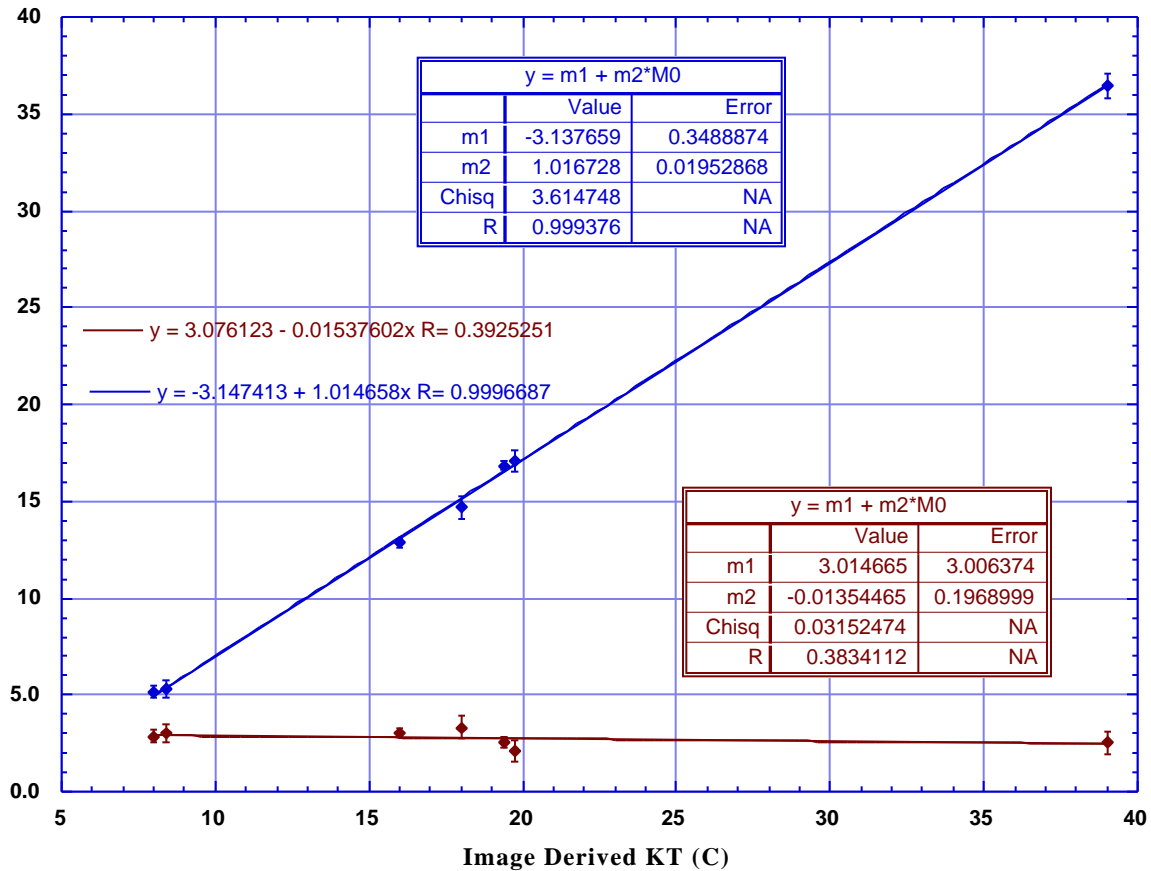
## **Science Results**

The objective of this proposal is to validate the thermal infrared data and products from the MODIS and ASTER sensors on the Terra platform. The Terra platform was launched in December 1999 but, due to technical difficulties, did not reach orbit until several months later. As a result, Level 1 data (radiance at sensor) from both ASTER and MODIS are only just becoming available and Level 2 data (temperature and emissivity) is unavailable. Work is underway on these preliminary Level 1 data but it is too early in the validation work to present results.

In the interim, the data from the sites are being used to validate other satellite and airborne sensors. Below is an example of some results from validation work involving a spaceborne instrument: the Landsat Enhanced Thematic Mapper (ETM+). For an example of validation of an airborne instrument see the 1999 status report.

Landsat ETM+ was launched approximately 7 months prior to the launch of Terra and thus validation data are available over the annual skin temperature cycle at Lake Tahoe ( $\sim 5 - 25^{\circ}\text{C}$ ). The temperature data from Lake Tahoe were provided to F. Palluconi (Landsat Science Team member) and used by Palluconi to validate the thermal infrared channel of Landsat ETM+. The results are summarized in Figure 3 and indicate a substantial error of approximately 3 degrees in the calibration of the Landsat thermal channel. While this error is clearly serious, it appears to be constant over time and temperature (Figure 3). Therefore it should be possible to update the calibration constants at the data processing center so that subsequent datasets are better calibrated or provide a correction algorithm for users. It should be emphasized that while the error appears nearly constant over time and temperature at present, it could change due to some change in the instrument and therefore requires further monitoring.

## KT Summary



**Figure 3 In Situ Derived Kinetic Temperature and Kinetic Temperature Difference (Image derived minus In situ) versus Image Derived Kinetic Temperature. (Plot courtesy of F. Palluconi)**

## Publications and Media

- Hook, S. J. 1998. In Flight Validation of Thermal Infrared Data over Land. European Symposium on Remote Sensing: SENSORS, SYSTEMS AND NEXT GENERATION SATELLITES IV, Barcelona, Spain, September 21-25. (Abstract).
- Hook, S. J., Myers, J. J., Thome, K. J., Fitzgerald, M. and A. B. Kahle, 1999. The MODIS/ASTER Airborne Simulator (MASTER) – A New Instrument for Earth Science Studies. Accepted Remote Sensing of Environment.

Hook, S. J., Schladow, G., Abtahi, A. F. Prata and B. Richards. In-Flight Validation of Remotely Sensed Thermal Infrared Data for Hydrological Applications. American Geophysical Union, San Francisco. (Abstract)

Hook, S. J., G. Schladow, A. Abtahi, F. Prata, B. Richards and S. Palmarsson. Validation of ASTER and MODIS Thermal Infrared Products. Sixth International Conference Remote Sensing for Marine and Coastal Environments. Charleston, South Carolina, May 1-3 2000. (Abstract)

Hook, S. J. 2000. MASTER – A New Instrument for Hyperspectral Analysis from the Visible to Thermal Infrared. 2<sup>nd</sup> EARSeL Workshop on Hyperspectral Imaging, Enschede, The Netherlands, July 11-13. (Abstract).

Tahoe World January 13 2000. 1.3 billion satellite links Tahoe to NASA ***By Shannon Darling, Tahoe World Staff.***

Tahoe World March 10, 2000. NASA rafts await satellite data ***By Shannon Darling, Tahoe World Staff.***

## **Collaborations**

Strong collaborations have been established with the ASTER, MODIS and Landsat ETM+ instrument teams. Data from the sites will be used to validate the thermal infrared radiance at sensor and surface temperature and emissivity products for these sensors. An example of how the data have been used to validate the Landsat thermal infrared radiance at sensor product is given in the Science Results section.

## **Archiving**

A web site has been established and this will be the primary mechanism for disseminating information. All data on the site are backed up as part of the main ASTER archive over the network and also locally on a nightly basis.

## **Future Plans**

- 1) Validate ASTER and MODIS thermal infrared data and products at all sites (ongoing).
- 2) Replace Mk II radiometers with Mk III radiometers. The Mk III radiometers include a nulling blackbody and should be more accurate than the Mk II radiometers (July 2000).
- 3) Add meteorological station to TR3. Meteorological station will include wind speed, wind direction, relative humidity, pressure and a net radiometer (September 2000).

- 4) Establish a calibration protocol for all instruments, especially the radiometers and temperature loggers. This will involve cross comparison of the instrumentation developed for the Australian and US sites (August 2000).
- 5) Deploy scanning radiometer at Amburla site (June 2000).
- 6) Re-installation of equipment at Thangoo site damaged by fire and cyclones (June 2000).

The following items were completed in FY 2000 as scheduled.

- 1) Deployment of TR3 and TR4 and addition of a shadow band radiometer at the Tahoe site.
- 2) Installation of a total sky imager at the Tahoe site.
- 3) Installation of scanning radiometers at the Uardry site.
- 4) Establish dial-up communication system with the Tahoe site to acquire real-time temperature and atmospheric data.
- 5) Update the web site to include example data sets including interactive analysis.
- 6) Continue preparation for validating ASTER and MODIS data by validating similar airborne and satellite instruments.
- 7) Develop error budgets.

## **Schedule**

The Tahoe, Amburla and Uardry sites are now fully operational and the highest priority task is to validate the thermal infrared data and products from MODIS and ASTER. This will be ongoing since we want to obtain cloud-free data over a range of temperatures. There are several other tasks, all of which involve improvements to the infrastructure or instrumentation at the sites, and the approximate time for these is listed with the future plans.

## **HomePage**

<http://shookweb.jpl.nasa.gov/validation>